Fishery Data Series No. 11-06

Coho Salmon Thermal-Marked Otolith Recovery, Resurrection Bay, Alaska, 2003–2005

by

Dan Bosch

May 2011

Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_2$, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

FISHERY DATA SERIES NO. 11-06

COHO SALMON THERMAL-MARKED OTOLITH RECOVERY, RESURRECTION BAY, ALASKA, 2003–2005

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ABSTRACT

The coho salmon *Oncorhynchus kisutch* sport fishery in Resurrection Bay, Alaska, has grown from an annual average harvest of about 16,000 fish (1977–1989) to an annual average of about 80,000 fish in 2005. This fishery is perhaps the largest sport fishery for coho salmon in Alaska. Coho salmon have been stocked into Resurrection Bay waters since the 1960s. The Alaska Department of Fish and Game (ADF&G) along with the Cook Inlet Aquaculture Association annually stock between 400,000 and 500,000 coho smolt into these waters. Starting in 2002 all coho salmon smolt released by hatcheries into Resurrection Bay, Cook Inlet, and Prince William Sound had thermally marked otoliths indicating their hatchery of origin as well as their release site. These coho salmon returned to their release sites during 2003–2005. ADF&G examined coho salmon from the Resurrection Bay sport fishery at the Port of Seward during these 3 years. The Resurrection Bay fishery was divided into three separate recovery areas, two of which were within the bay, and the third was outside the bay. During the 3 years of sampling (2003, 2004 and 2005) 33%, 24%, and 33% of the samples were thermally marked fish. The recovery area at the head of Resurrection Bay, adjacent to the Port of Seward, had the highest contribution of thermally marked coho salmon. More thermally marked coho salmon were recovered each year after July 31 than prior to August 1. Thermally marked coho from release sites in Resurrection Bay, Prince William Sound and Cook Inlet were recovered. The most frequently recovered coho were released from hatcheries in Resurrection Bay followed closely by fish released in Prince William Sound.

Key words: coho salmon smolt, Resurrection Bay, thermally marked, otoliths, Seward, unmarked otoliths

INTRODUCTION

The North Gulf Coast marine fishery extends from Cape Puget to Gore Point and includes Resurrection Bay (Figure 1). Most of the recreational harvest of fish from this area is landed at the Port of Seward, located at the head of Resurrection Bay. Seward, the only port in the North Gulf Coast area, is located 127 miles south of Anchorage and has become a recreational hub for marine sport fishermen from all over Southcentral Alaska. Fishing for salmon in freshwater drainages of Resurrection Bay has been illegal since before statehood, so all effort directed toward salmon takes place in salt water. Recreational fishing effort (Table 1) in this area, as estimated from the Alaska Department of Fish and Game's (ADF&G) annual mail survey of licensed sport anglers (Statewide Harvest Survey or SWHS), has progressively increased from an average of about 48,000 angler-days during 1977-1986 to 71,500 angler-days during 1987-1996, and 94,200 angler-days during 1997-2005 (Howe et al. 1995-1996, 2001a-d; Jennings et al. 2004, 2006a-b, 2007, 2009; Mills 1979-1980, 1981a-b, 1982-1994; Walker et al. 2003). North Gulf Coast anglers target a variety of fish including all five species of Pacific salmon, Dolly Varden *Salvelinus malma*, rainbow trout *Oncorhynchus mykiss*, rockfish *Sebastes*, Pacific halibut *Hippoglossus stenolepis*, lingcod *Ophiodon elongates*, and sharks. Sport fisheries for salmon are supported by a combination of wild and hatchery-produced stocks. Coho salmon *O. kisutch* are the target species of choice in terms of numbers caught.

Resurrection Bay supports one of the largest marine coho salmon sport fisheries in the Pacific Northwest. While 57% of the coho salmon harvested from 1995 through 2004 were by anglers in private boats, a shorebased fishery on beaches in and near Seward accounted for about 12% of the total coho salmon harvest in those years. A growing charter boat fleet transports anglers who harvest the remaining 31% (Table 1). Between 1977 and 2005, the marine harvest of coho salmon ranged from 9,727 in 1984 to a peak of 135,946 in 2005 (Table 1). The 9-day Seward Silver Salmon Derby, which has been held each August since 1956, highlights this fishery. During 2003, in celebration of Seward's Centennial, the Seward Silver Salmon Derby was 16 days, from August 9 to August 24. The Alaska Board of Fisheries (BOF) recognized the importance of the Resurrection Bay coho salmon sport fishery, and in 1966 developed the Resurrection Bay Salmon Management Plan (5 AAC 21.376), which gave the sport fishery exclusive use of the bay's coho salmon.

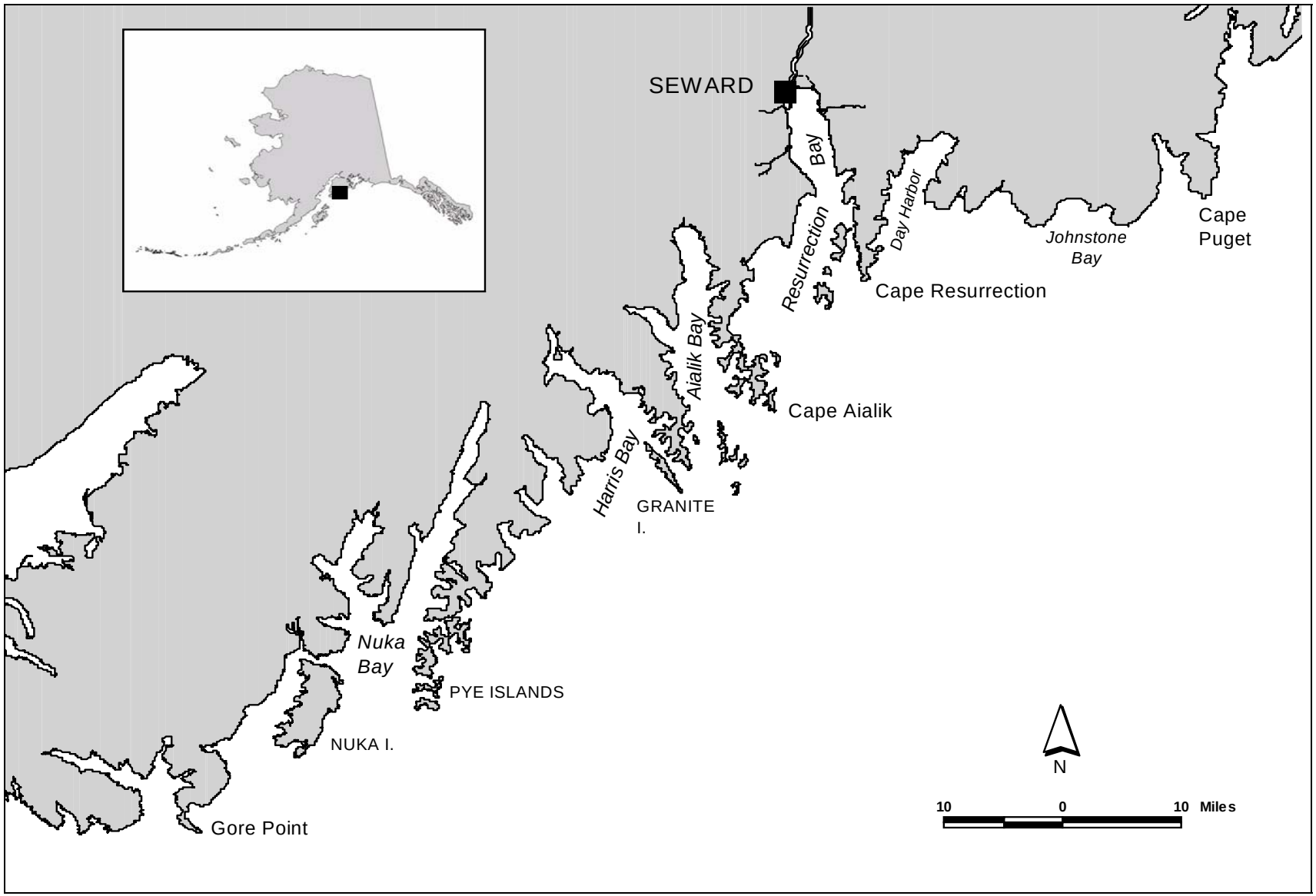

Figure 1.–The North Gulf Coast management area including Resurrection Bay.

Table 1.–Fishing effort (angler-days) and the estimated catch and harvest of coho salmon landed at the Port of Seward, 1977-2005.

Year[a]	Saltwater angler effort[b]	Boat						Shore		Total	
		Charter		Private		Total					
		Catch	Harvest	Catch	Harvest	Catch	Harvest	Catch	Harvest	Catch	Harvest
1977	41,797										14,528
1978	53,355										16,731
1979	43,576										14,315
1980	49,623										19,665
1981	56,410										14,721
1982	49,167										18,518
1983	40,144										11,277
1984	44,669										9,727
1985	47,472										11,227
1986	51,375		2,125		8,364		10,489		3,929		14,418
1987	42,143		2,209		16,652		18,861		5,359		24,220
1988	50,251		1,473		9,932		11,405		6,221		17,626
1989	47,386		2,889		13,444		16,333		2,851		19,184
1990	69,485	10,039	7,487	21,392	16,631	31,431	24,118	8,403	5,643	39,834	29,761
1991	71,332	8,265	7,335	20,484	18,452	28,749	25,787	5,827	5,177	34,576	30,964
1992	80,814	5,830	5,263	19,199	15,976	25,029	21,239	7,823	6,665	32,852	27,904
1993	85,559	13,957	12,907	31,728	27,018	45,685	39,925	8,512	7,647	54,197	47,572
1994	85,742	6,872	6,377	23,510	21,248	30,382	27,625	11,337	10,840	41,719	38,465
1995	99,689	9,150	8,172	25,737	21,713	34,887	29,885	12,717	10,213	47,604	40,098
1996	81,499	24,093	18,696	51,346	41,898	75,439	60,594	19,217	15,214	94,656	75,808
1997	89,686	30,300	24,010	75,463	50,188	105,763	74,198	16,771	13,015	122,534	87,213
1998	71,034	19,501	16,288	63,145	42,552	82,646	58,840	11,537	10,306	94,183	69,146
1999	84,637	29,891	24,053	54,169	44,500	84,060	68,553	8,628	7,067	92,688	75,620
2000	83,551	25,706	22,708	47,222	42,079	72,928	64,787	7,186	5,984	80,114	70,771
2001	91,477	41,739	36,873	53,011	45,990	94,750	82,863	15,969	13,607	110,719	96,470
2002	97,351	38,944	34,018	62,642	54,811	101,586	88,829	10,486	9,730	112,072	98,559
2003	95,579	35,278	29,998	59,643	46,423	94,921	76,421	10,400	8,293	105,321	84,714
2004	117,941	40,552	32,599	88,060	69,087	128,612	101,686	8,318	6,230	136,930	107,916
2005	115,605	50,211	43,371	107,126	81,440	157,337	124,811	13,399	11,135	170,736	135,946

Source: Howe et al. 1995-1996, 2001a-d; Jennings et al. 2004, 2006a-b, 2007, 2009; Mills 1979-1980, 1981a-b,1982-1994; Walker et al. 2003

[a] 1996–1999 catch and harvest estimates were recalculated due to error in original, published data analysis. Estimates starting in 2001 are based on port of origin rather than origin of catch.

[b] Effort is a total estimate of effort directed at all fish, and is not species specific.

In 1976, BOF modified the plan to stipulate that the commercial fishery for pink and chum salmon be managed so that it does not interfere with the recreational coho and Chinook salmon fisheries. During their November 2001 meeting, BOF created the Resurrection Bay Terminal Harvest Area for coho salmon. This area includes all marine waters in Resurrection Bay north of a line extending from Cape Resurrection to Cape Aialik. Bag and possession limits of 6 coho salmon inside the terminal harvest area remain in effect. A bag and possession limit of 3 coho salmon has been in effect since 2002 in North Gulf Coast marine waters (Cape Puget to Gore Point) outside the terminal harvest area.

Enhancement programs in the Resurrection Bay area (Table 2) include stocking Bear Lake (since 1964) with coho salmon and annual plants of hatchery-reared smolt at a variety of local release sites (since 1969). ADF&G currently has a stocking goal of 240,000 coho smolt at two Resurrection Bay locations: Lowell Creek (120,000) and Seward Lagoon (120,000). The Seward Chamber of Commerce also buys coho smolt each year from the Cook Inlet Aquaculture Association (CIAA), and releases them into Bear Creek. CIAA has a permit to release up to 250,000 coho smolt into Bear Creek. The Chamber typically purchases 120,000 smolt each year, but raised enough money in 2002 to purchase 250,000. As part of their contractual agreement to operate the Trail Lakes Hatchery, CIAA also releases about 400,000 coho fry annually into Bear Lake.

All freshwater drainages of Resurrection Bay were closed to salmon sport fishing from 1960 through 2004. BOF opened a small portion of the Resurrection River drainage to salmon fishing starting in 2005. The Resurrection River drainage downstream of the Seward Highway and Nash Road is open to salmon fishing from August 1 through December 31 each year. The daily bag and possession limit in the small freshwater area is 3 salmon of which 2 may be coho salmon.

In 2004, the Alaska SeaLife Center in Seward, CIAA, and MariCal (a company from Portland, Maine) started a smoltification experiment on coho salmon. MariCal developed a product that initiates the smolting process in salmon fingerlings. The product is intended to ensure that fully smolted salmon enter salt water, which in turn increases immediate and overall marine survival. These experiments lead to the release of a record 813,787 coho salmon smolt into Resurrection Bay in 2004 (Table 2).

The average yearly coho salmon harvest in Resurrection Bay increased dramatically from an annual average of 15,858 fish (1977-1989) to a 5-year average (2001-2005) of 103,591 fish (Howe et al. 1995-1996, 2001a-d; Jennings et al. 2004, 2006a-b, 2007, 2009; Mills 1979-1980, 1981a-b, 1982-1994; Walker et al. 2003). During 2005, anglers fishing from the Port of Seward caught a record 170,736 coho and harvested a record 135,946 of these fish. The current goal of the Resurrection Bay coho salmon stocking plan is to produce a return of 20,000 adult coho and generate 25,000 angler-days of effort. It is assumed that the dramatic increase in magnitude of the coho salmon fishery in terms of catch and harvest returned to the Port of Seward is supported by stocks other than those returning to Resurrection Bay (i.e., mixed stock of wild and hatchery fish planted outside of Resurrection Bay). This study was deemed necessary to determine if the increased coho salmon harvest is predominantly due to contributions from hatchery or wild stocks. Stocking levels in Resurrection Bay alone do not appear to account for increased harvest levels.

Table 2.-Coho salmon smolt releases by organization and location, 1990-2004.

VFDA smolt releases															
Release Site/Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Boulder Bay	20,000	0	19,568	0	13,784	20,000	20,000	21,768	16,388	19,810	0	13,000	20,000	0	0
Port Valdez	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solomon Gulch	787,137	975,521	1,206,476	461,388	901,303	1,305,316	1,855,823	1,293,145	1,732,098	1,843,718	1,625,599	1,503,328	1,821,889	1,275,145	1,442,272
Tatitlek	0	31,248	0	0	0	0	0	0	0	0	0	0	0	20,000	0
Total Smolt Releases	807,137	1,006,769	1,226,044	461,388	915,087	1,325,316	1,875,823	1,314,913	1,748,486	1,863,528	1,625,599	1,516,328	1,841,889	1,295,145	1,442,272
PWSAC Smolt Releases															
Crab Bay	0	0	0	0	0	0	0	0	0	56,467	47,395	50,341	48,935	53,594	50,000
Flemming Spit		40,080	123,658	0	0	100,260	49,845	49,583	102,955	99,943	93,000	73,949	100,435	100,781	89,893
Lake Bay	2,460,620	2,083,292	1,563,711	0	0	1,861,922	176,913	104,944	205,518	830,243	187,775	47,861	241,545	666,541	749,598
Whittier Harbor	0	100,254	143,829	0	0	101,774	48,648	49,124	99,242	81,685	47,500	49,816	94,919	99,942	99,892
Whittier/Flemming/Lake	0	0	0	1,303,077	1,484,936	0	0	0	0	0	0	0	0	0	0
Total Smolt Releases	2,460,620	2,223,626	1,831,198	1,303,077	1,484,936	2,063,956	275,406	203,651	407,715	1,068,338	375,670	221,967	485,834	920,858	989,383
ADF&G Smolt Releases															
Bird Creek	0	0	0	0	84,643	154,753	147,618	294,565	164,211	111,105	97,409	0	0	0	109,949
Campbell Creek	0	0	97,076	140,797	87,686	157,241		71,519	83,317	42,046	63,730	69,836	61,323	78,576	85,790
Campbell & Ship Ck	0	0	0	0	0	0	302,857	0	0	0	0	0	0	0	0
Eklutna Tailrace	0	0	0	0	0	0	0	0	112,219	126,602	76,851	124,838	120,629	120,736	131,979
Homer Spit	122,945	100,236	100,570	116,129	156,213	110,701	149,000	120,242	130,219	129,602	122,338	225,042	216,355	222,735	130,243
Lowell Creek	63,733	30,400		64,361	38,000	50,698	69,000	61,687	65,687	62,580	54,184	125,618	119,512	124,389	131,989
Seward Lagoon	145,619	119,057	98,700	159,091	221,577	133,700	182,000	144,112	74,365	109,142	145,693	124,703	121,743	123,718	131,798
Ship Creek	64,006	57,800	67,178	54,764	75,799	158,981	0	232,066	232,765	165,388	260,070	233,563	212,639	234,716	241,066
Total Smolt Releases	396,303	307,493	363,524	535,142	663,918	766,074	850,475	924,191	862,783	746,465	820,275	903,600	852,201	904,870	962,814
CIAA															
Bear Creek	93,700	0	51,700	0	0	7,400	75,000	153,000	117,000	51,000	102,000	120,500	123,800	253,000	285,000
Bear Lake (out-migrants)[a]	80,271	97,512	112,800	53,397	54,415	89,163	154,892	114,021	91,906	106,799	70,879	101,356	94,173	208,100	73,000
SeaLife Center release	0	0	0	0	0	0	0	0	0	0	0	0	0	0	192,000
Total Smolt Releases	173,971	97,512	164,500	53,397	54,415	96,563	229,892	267,021	208,906	157,799	172,879	221,856	217,973	461,100	550,000
Total Res Bay Releases	383,323	246,969	263,200	276,849	313,992	280,961	480,892	472,820	348,958	329,521	372,756	472,177	459,228	709,207	813,787
Total PWS Releases	3,267,757	3,230,395	3,057,242	1,764,465	2,400,023	3,389,272	2,151,229	1,518,564	2,156,201	2,931,866	2,001,269	1,738,295	2,327,723	2,216,003	2,431,655
Total CI Releases	186,951	158,036	264,824	311,690	404,341	581,676	599,475	718,392	722,731	574,743	620,398	653,279	610,946	656,763	699,027
Total	3,838,031	3,635,400	3,585,266	2,353,004	3,118,356	4,251,909	3,231,596	2,709,776	3,227,890	3,836,130	2,994,423	2,863,751	3,397,897	3,581,973	3,944,469

[a] A combination of hatchery fed fry and wild coho that rear in the lake.

Both charter and private anglers continue to venture farther out of Resurrection Bay or target coho salmon earlier in the season. Anecdotal evidence suggests that a substantial number of coho salmon caught in the Resurrection Bay fisheries are most likely from adjacent coho salmon stocks in Prince William Sound (PWS). Since 1985, two nonprofit hatcheries, Prince William Sound Aquaculture Cooperation (PWSAC) and Valdez Fisheries Development Association (VFDA), annually release on average about 2,215,774 coho smolt into Prince William Sound. Over the 10-year period (1995-2004) the annual average number of coho salmon smolt released into Resurrection Bay, Prince William Sound, and Cook Inlet was about 3,400,000. Kitoi Bay Hatchery, on the south side of Afognak Island, also releases a large number of coho salmon smolt into the Gulf of Alaska. Since 1999, it annually releases an average of 1,002,581 smolt, 273,805 fed fry, and 12,000 pre-smolt.

Since 2002, 100% of all hatchery-reared coho salmon released into Resurrection Bay (ADF&G, CIAA), Cook Inlet (ADF&G, CIAA), and Prince William Sound (PWSAC, VFDA) have thermal marked otoliths (Table 3). Hatchery-reared adult coho returning to release sites in Cook Inlet, Resurrection Bay, and Prince William Sound during the 2003 season had thermal marked otoliths. Coho salmon released from Kitoi Bay were not thermally marked or coded-wire-tagged, making their identification impossible.

This study was designed to estimate the contribution of each hatchery by time and area of harvest to the coho salmon harvest "landed" at the Port of Seward. The origin of the unmarked contribution to the harvest cannot be discriminated as wild or hatchery, but the total unmarked contribution was estimated.

METHODS

Coho salmon harvested by recreational anglers that were landed in Seward were sampled and grouped by time and area in which they were caught. Samples were collected only from catches taken entirely in one of the three recovery areas (Table 4, Figure 2). In 2003 and 2004, there were six sampling periods, whereas the 2005 season had only five sampling periods (Table 5).

A sample-size goal of 96 coho salmon was set for each area and sampling period. The sagital otoliths were extracted and length from mid eye to fork was measured for all coho salmon sampled. Each set of otoliths was ground, mounted and examined under a dissecting microscope to determine if it was marked or unmarked. It was assumed that all hatchery stocks contributing to the recreational fisheries had thermal marked otoliths. In addition, all stocked fish were thermally treated to create unique (by hatchery) banding patterns in their otoliths that could be classified upon visual inspection. The hatchery composition of coho captured within each study area and sampling stratum was estimated as a proportion.

A sample-size goal of 96 coho salmon per unique stratum (combination of area and sampling period) was expected to provide estimated hatchery contributions within 10 percentage points of their true values 95% of the time. The sample size was determined by treating each estimate as a binomial proportion[1] and using the procedures outlined by Cochran (1977, equations 4.2 and 4.3) with an assumed hatchery contribution of 50% (providing the most conservative sample sizes).

[1] Each harvested fish was either from one of the thermally marked hatchery stocks or it was from an unmarked stock (wild or hatchery in 2003).

Table 3.-Hatchery coho salmon smolt released into Resurrection Bay, Cook Inlet, and Prince William Sound, 2002–2004, that returned to release sites, 2003-2005.

Release site by organization	Number released 2002 (returned in 2003)	Number released 2003 (returned in 2004)	Number released 2004 (returned in 2005)	Thermal marked
Resurrection Bay				
ADF&G	241,255	248,107	264,000	Yes
CIAA	217,973[a]	253,400	477,000[b]	Yes
Cook Inlet				
ADF&G	610,946	656,763	613,000	Yes
CIAA	None	103,400	103,000[c]	Yes
Prince William Sound				
ADF&G	None	None	None	None
PWSAC	485,834	920,858	989,400	Yes
VFDA	1,841,889	1,295,473	1,442,300	Yes
Total	3,397,897	3,882,473	3,971,700	Yes

Note: Use of a product name does not constitute endorsement.

[a] 123,800 smolt released into Bear Creek, another 94,173 smolt counted emigrating out of Bear Lake (not all marked).

[b] 285,000 smolt treated with SuperSmolt® released at Bear Creek Weir, another 192,000 smolt treated with SuperSmolt released in Resurrection Bay in front of SeaLife Center, and 73,000 smolt counted outmigrating from Bear Lake.

[c] These coho smolt were purchased by Homer and released at the Nick Dudiak Fishing Lagoon and have the same thermal mark as CIAA coho smolt released into Resurrection Bay.

Table 4.-Sampling area definitions for the Resurrection Bay coho salmon fishery assessment.

Area	Sampling area description[a]
1	All Resurrection Bay waters north of a line from Caines Head to a point at the entrance of Humpy Cove.
2	All Resurrection Bay waters south of a line from Caines Head to a point at the entrance of Humpy Cove, and all waters north of a line from Cape Aialik to Cape Resurrection.
3	All North Gulf Coast waters outside Resurrection Bay.

[a] Resurrection Bay is defined as all saltwater north of a line from Cape Aialik to Cape Resurrection.

Table 5.-Sampling periods for the Resurrection Bay coho salmon fishery assessment, 2003–2005.

Period	2003	2004	2005
1	Jul 5–15	Jul 1–15	Jul 6–15
2	Jul 16–31	Jul 16–31	Jul 16–31
3	Aug 1–8, Pre Silver Salmon Derby	Aug 1–6, Pre Silver Salmon Derby	Aug 1–12, Pre Silver Salmon Derby
4	Aug 9–24, Silver Salmon Derby	Aug 7–21, Silver Salmon Derby	Aug 13–27, Silver Salmon Derby
5	Aug 25–31, Post Silver Salmon Derby	Aug 22–31, Post Silver Salmon Derby	Only 4 days sampled[a]
6	Sep 1–15	Sep 1–15	Aug 28–Sep 15

[a] Seward Silver Salmon Derby did not end until August 27, 2005, so August 28–31 sampling was included in Period 6.

In Resurrection Bay, the SWHS collects harvest information from three different angler types: anglers who use charter boats, private boats, and anglers who fish from shore. A large military recreation camp in Seward also provides boats for angling to military personnel. However, anglers fishing from these military boats report their harvest as both private and charter (Scott Meyer, Alaska Department of Fish and Game, Homer, personal communication).

Sampling protocols were directed to collect otoliths from harvested coho salmon in proportion to the harvest by angler type. The estimated 10-year average (1995-2004) for the total harvest of coho salmon at Seward is 57% from private boats, 31% from charter boats and 12% from shore anglers. Ignoring the shorebased component of the harvest (which takes place later in the season), the estimated 10-year average harvest of coho salmon from boat anglers only is 31% from charter boats and 69% from private boats. There were 65-70 otoliths collected from each area during a particular sampling period from private boat anglers. The remainder of the total sample size of 96 was collected from charter boat anglers. Coho salmon otoliths were collected

each year during the first four sampling periods in Areas 2 and 3. Coho salmon were not available to shore anglers in Area 1 until periods 5 and 6. During 2003, otoliths from the shore fishery were collected during a 2-day sampling event each of the last two periods. In 2004 and 2005 otoliths collected during the shore fishery were collected throughout the last sampling period (Table 5). During all other sampling, the collection of otoliths was not concentrated during any particular time period, but rather collected evenly over the entire period. An example of the sampling schedule, along with target sample size guidelines, is provided in Appendix A.

DATA COLLECTION

The following information was collected and recorded during each interview:

1. Date
2. Sample number
3. Angler type: charter boat, private boat, military boat, shore
4. Harvest location : Area 1, Area 2, Area 3
5. Were all coho harvested from the same area?
6. Interview location
    a. J-dock
    b. Main Dock
    c. South boat ramp
    d. North boat ramp
    e. Military camp
    f. Shoreline (Lowell Creek, Seward Lagoon outflow, Eastside Resurrection Bay)
7. Number of otoliths collected from sample.
8. The location in a cell tray of each otolith sample collected.
9. Length from mid eye to fork of each fish sampled.

A total of 96 pairs of coho salmon otoliths from each area and sampling period were collected and stored in a cell tray. Samples from some areas such as the shoreline stocking areas at Lowell Creek and Seward Lagoon Outfall were not collected until late August and early September when coho salmon typically become available for harvest. During all sampling periods (Table 5) each interview location was explored to ensure the data collected was distributed over all user groups. July consisted of two sampling periods, whereas August usually consisted of three periods. During 2003, samples from Areas 2 and 3 were not collected due to a lack of personnel. However, some samples were collected from these two areas in 2004 and 2005. Samples from Area 1 were collected each year during these late periods.

DATA ANALYSIS

The hatchery composition of coho salmon captured within each study area by sampling period was estimated as a binomial proportion ($\hat{p}_h$):

$$\hat{p}_h = \frac{y_h}{n_h} \tag{1}$$

where:

y_h = the number of sampled coho salmon from a sample area determined to be of hatchery origin during each sampling period; and

n_h = the total number of coho salmon sampled from that area during each sampling period, that can be classified as hatchery or non-hatchery.

The variance of $\hat{p}_h$ was estimated as (Cochran 1977):

$$\hat{V}[\hat{p}_h] = \frac{\hat{p}_h(1-\hat{p}_h)}{n_h - 1} \tag{2}$$

A chi-square test of homogeneity while controlling for year effects was performed to determine if the estimated proportion of marked fish sampled prior to August 1 was equal to the estimated proportion of marked fish sampled after July 31 throughout the entire study area. The test used a set of three 2 x 2 tables with rows for fish recovered during July and columns for marked and unmarked fish.

RESULTS

In 2003, 2004, and 2005 coho salmon otoliths were collected at the Port of Seward from early July through the middle of September (Table 6). During both 2004 and 2005, otolith samples were collected throughout each sampling period and from all harvest areas (Table 6). During 2003, the Area 1 shore fishery (and adjacent waters) was sampled on August 30 and 31, and September 11 and 12. In 2003, there were no samples collected from Areas 2 and 3 during the last two periods because no staff were available. Fortunately, fishing effort was light in these areas because of rough ocean conditions and relatively few coho salmon were present.

In 2004 and 2005, fishing effort and harvest of coho salmon reached all time highs. Angler effort ranged from an estimated 95,579 angler-days in 2003 to a record 117,941 angler-days in 2004 (Table 1). The dramatic increase in effort in 2004 was attributed to angler's escaping smoke from the record number of forest fires in the interior of Alaska. During 2005, an estimated record 170,736 coho salmon were caught while an estimated 135,946 of these fish were harvested. During 2004, anglers complained all season about catching and releasing numerous juvenile coho, presumably smolt, that had just entered the ocean that spring. Anecdotal reports from charter operators fishing in the North Gulf and Prince William Sound indicated anglers were catching up to 40-50 of these juvenile coho salmon a day. ADF&G collected 18 of the juvenile coho and determined that most were wild or had unmarked otoliths. These large catches of young coho indicate that the initial marine survival of coho salmon smolt was extremely high in North Gulf Coast waters in 2004.

There were 1,031 readable coho salmon otoliths sampled and processed in 2003, 1,273 in 2004, and 1,183 in 2005 (Table 6). Combining all areas and sampling periods in 2003, 2004, and 2005, the respective estimated proportions of hatchery origin coho salmon were 33% (SE = 0.015), 24% (SE = 0.012), and 33% (SE = 0.021).

Table 6.-Proportion of marked and unmarked coho salmon otoliths collected by sampling period and area, 2003-2005.

Area 1: Marked vs Unmarked				**2003**			
Period	n[a]	Marked	Unmarked	% Hatchery	Var (Hatch)	SE (Hatch)	% Unmarked
Jul 5 –15	3	1	2	33%	0.111	0.333	67%
Jul 16–31	35	9	26	26%	0.006	0.075	74%
Aug 1–8	42	21	21	50%	0.006	0.078	50%
Aug 9–24 (Derby)	96	57	39	59%	0.003	0.050	41%
Aug 25–31	90	42	48	47%	0.003	0.053	53%
Sep 1–15 (Beach)	73	48	25	66%	0.003	0.056	34%
Total	339	178	161	53%	0.001	0.027	47%
Area 2: Marked vs Unmarked							
Period	n[b]	Marked	Unmarked	% Hatchery	Var (Hatch)	SE (Hatch)	% Unmarked
Jul 5–15	96	4	92	4%	0.000	0.021	96%
Jul 16 –31	92	18	74	20%	0.002	0.042	80%
Aug 1–8	41	17	24	41%	0.006	0.078	59%
Aug 9 –24 (Derby)	91	35	56	38%	0.003	0.051	62%
Total	320	74	246	23%	0.001	0.024	77%
Area 3: Marked vs Unmarked							
Period	n[c]	Marked	Unmarked	% Hatchery	Var (Hatch)	SE (Hatch)	% Unmarked
Jul 5–15	88	7	81	8%	0.001	0.029	92%
Jul 16–31	93	18	75	19%	0.002	0.041	81%
Aug 1–8	96	30	66	31%	0.002	0.048	69%
Aug 9–24 (Derby)	95	29	66	31%	0.002	0.047	69%
Total	372	84	288	23%	0.000	0.022	77%
Total All Areas	1,031	336	695	33%	0.000	0.015	67%
Area 1: Marked vs Unmarked				**2004**			
Period	n	Marked	Unmarked	% Hatchery	Var (Hatch)	SE (Hatch)	% Unmarked
Jul 1–15	41	1	40	2%	0.001	0.024	98%
Jul 16–31	87	9	78	10%	0.001	0.033	90%
Aug 1–6	59	13	46	22%	0.003	0.054	78%
Aug 7–20 (Derby)	96	36	60	38%	0.002	0.050	63%
Aug 21–31	58	30	28	52%	0.004	0.066	48%
Sep 1–15 (Beach)	95	81	14	85%	0.001	0.037	15%
Area 1 Total	436	170	266	39%	0.001	0.023	61%
Area 2: Marked vs Unmarked							
Period	n	Marked	Unmarked	% Hatchery	Var (Hatch)	SE (Hatch)	% Unmarked
Jul 1–15	96	2	94	2%	0.000	0.015	98%
Jul 16–31	96	8	88	8%	0.001	0.028	92%
Aug 1–6	87	23	64	26%	0.002	0.048	74%
Aug 7–20 (Derby)	96	32	64	33%	0.002	0.048	67%
Aug 21–31	16	7	9	44%	0.016	0.128	56%
Sep 1–15 (Beach)	9	3	6	33%	0.028	0.167	67%
Area 2 Total	400	75	325	19%	0.000	0.020	81%
Area 3: Marked vs Unmarked							
Period	n	Marked	Unmarked	% Hatchery	Var (Hatch)	SE (Hatch)	% Unmarked
Jul 1–15	91	6	85	7%	0.001	0.026	93%
Jul 16–31	92	10	82	11%	0.001	0.033	89%
Aug 1–6	96	12	84	13%	0.001	0.034	88%
Aug 7–20 (Derby)	96	19	77	20%	0.002	0.041	80%
Aug 21–31	32	5	27	16%	0.004	0.065	84%
Sep 1–15 (Beach)	30	11	19	37%	0.008	0.089	63%
Area 3 Total	437	63	374	14%	0.000	0.017	86%
Total All Areas	1,273	308	965	24%	0.000	0.012	76%

-continued-

Table 6.–Page 2 of 2.

Area 1: Marked vs Unmarked				**2005**			
Period	*n*	Marked	Unmarked	% Hatchery	Var (Hatch)	SE (Hatch)	% Unmarked
Jul 6–15	8	3	5	38%	0.033	0.183	63%
Jul 16–31	32	8	24	25%	0.006	0.078	75%
Aug 1–12	4	2	2	50%	0.083	0.289	50%
Aug 13–27 (Derby)	89	42	47	47%	0.003	0.053	53%
Aug 28–Sep 15	132	109	23	83%	0.001	0.033	17%
Area 1 Total	265	164	101	62%	0.001	0.030	38%
Area 2: Marked vs Unmarked							
Period	*n*	Marked	Unmarked	% Hatchery	Var (Hatch)	SE (Hatch)	% Unmarked
Jul 6–15	196	42	154	21%	0.001	0.029	79%
Jul 16–31	189	42	147	22%	0.001	0.030	78%
Aug 1–12	80	23	57	29%	0.003	0.051	71%
Aug 13–27 (Derby)	56	28	28	50%	0.005	0.067	50%
Aug 28–Sep 15	12	8	4	67%	0.020	0.142	33%
Area 2 Total	533	143	390	27%	0.000	0.019	73%
Area 3: Marked vs Unmarked							
Period	*n*	Marked	Unmarked	% Hatchery	Var (Hatch)	SE (Hatch)	% Unmarked
Jul 6–15	63	8	55	13%	0.002	0.042	87%
Jul 16–31	85	14	71	16%	0.002	0.040	84%
Aug 1–12	102	20	82	20%	0.002	0.040	80%
Aug 13–27 (Derby)	93	31	62	33%	0.002	0.049	67%
Aug 28–Sep 15	42	14	28	33%	0.005	0.074	67%
Area 3 Total	385	87	298	23%	0.000	0.021	77%
Total	*n*	Marked	Unmarked	% Hatchery	Var (Hatch)	SE (Hatch)	% Unmarked
All Areas	1,183	394	789	33%	0.000	0.014	67%

[a] Does not include 16 unreadable otoliths collected during periods 5 and 6

[b] Does not include 6 unreadable otoliths collected during periods 3 and 4.

[c] Does not include 4 unreadable otoliths collected during periods 1 and 2.

Samples were collected from private boat anglers, charter boat anglers, and shore anglers in Resurrection Bay in proportion to their historical use patterns (Table 1). Overall, the fewest samples were collected from shore anglers. The total proportion sampled from shore anglers ranged from 6% to 10% (Table 7). Anglers from charter boats harvested the next largest proportion of coho salmon in the North Gulf Coast. The proportion of samples collected from this group ranged from 35% in 2004 to 48% in 2005. Anglers from private boats harvested the most coho salmon and the proportion of samples collected from this group ranged from 36% in 2005 to 59% collected in 2004. The sample proportions collected from each of these groups during 2003 and 2004 matched closely with the actual proportions estimated in the SWHS (Table 1 and Table 7). In 2005, the proportion collected from shore anglers was similar to the actual harvest, whereas the sample proportions collected from charter and private boat anglers were not.

AREA 1: NORTH RESURRECTION BAY

There were 339 otoliths collected in 2003 in Area 1, 436 in 2004, and 265 in 2005. These otoliths were collected during all sampling periods (Table 6). We expected to see few coho salmon caught in Area 1 until early August and collected all samples we could from this area during July. Only during 2004 were there substantial numbers of coho salmon caught in Area 1 prior to August sampling (Table 6).

During 2003, 53% (SE = 0.027) of all the otoliths collected in Area 1 were of hatchery origin, whereas in 2004 and 2005, 39% (SE = 0.023), and 62% (SE = 0.030) were of hatchery origin.

During each year, it was typical to have a higher proportion of hatchery fish in this area as the season progressed. The proportion of hatchery coho salmon sampled ranged from 2% in 2004 during Period 1 (July 1-15) to 85% collected during Period 6 (September 1-15) the same year. The highest proportions of hatchery coho salmon were caught each year off the Seward city beaches during September (Table 6).

A majority (>90%) of the otoliths sampled in Area 1 came from coho salmon caught by private anglers fishing from shore and boats (Table 7). Samples from anglers fishing from private boats composed 60% to 80% of the total samples collected from Area 1 each year. The shore fishery, which typically does not start until late August or early September, composed 18% to 35% of the total samples collected. Anglers fishing from charter boats contributed <10% to the total samples each year.

Table 7.-Coho salmon otoliths collected by angler type, sampling area, and year.

Sum of otoliths collected by angler type during 2003				
Angler Type	Area 1	Area 2	Area 3	Total
charter	31	112	205	348
private	219	215	175	609
shore	105	0	0	105
Total	355	327	380	1062
Percentage of otoliths collected by angler type				
Angler Type	Area 1	Area 2	Area 3	Total
charter	9%	34%	54%	33%
private	62%	66%	46%	57%
shore	30%	0%	0%	10%
Total	100%	100%	100%	100%
Sum of otoliths collected by angler type during 2004				
Angler Type	Area 1	Area 2	Area 3	Total
charter	6	111	331	448
private	352	289	120	761
shore	80	0	0	80
Total	438	400	451	1289
Percentage of otoliths collected by angler type				
Angler Type	Area 1	Area 2	Area 3	Total
charter	1%	28%	73%	35%
private	80%	72%	27%	59%
shore	18%	0%	0%	6%
Total	100%	100%	100%	100%
Sum of otoliths collected by angler type during 2005.				
Angler Type	Area 1	Area 2	Area 3	Total
charter	15	248	355	618
private	158	276	30	464
shore	92	0	0	92
Total	265	524	385	1174
Percentage of otoliths collected by angler type				
Angler Type	Area 1	Area 2	Area 3	Total
charter	6%	47%	92%	53%
private	60%	53%	8%	40%
shore	35%	0%	0%	8%
Total	100%	100%	100%	100%

A similar number of hatchery coho salmon were recovered in Area 1 each year: 178 in 2003, 170 in 2004, and 164 in 2005 (Table 8). These hatchery coho were from release sites in

Resurrection Bay, Prince William Sound and Cook Inlet (Table 8). The majority of the hatchery-origin coho salmon recovered each year was originally released in Resurrection Bay. These were almost always recovered after August 1. ADF&G coho released at Lowell Creek and Seward Lagoon were the most commonly collected, followed by CIAA releases at Bear Creek. The number of coho collected that were originally released by ADF&G ranged from 123 in 2003 to 151 in 2004. Recovered coho salmon released by CIAA ranged from 19 in 2005 to 42 in 2004 (Table 8). Only 3 coho salmon originally released in Resurrection Bay were recovered prior to August 1.

Hatchery coho salmon originally released in Prince William Sound were also recovered in Area 1. These hatchery coho were released from both VFDA and PWSAC. Hatchery coho from VFDA were more commonly sampled than coho released from PWSAC (Table 8). Most of the Prince William Sound fish collected in Area 1 were caught before the Seward Silver Salmon Derby (Table 8). During 2003 and 2005, some coho from PWS hatcheries were caught off Seward city beaches.

Only two coho salmon released in Cook Inlet were recovered in Area 1. These fish were caught during the first week of August in 2003. Significantly fewer marked coho salmon were recovered from Area 1 during July than were recovered during August throughout the entire 3-year study (Cochran-Mantel-Haenszel $\chi^2 = 314.79$, df = 1, $P<0.0001$).

AREA 2: SOUTH RESURRECTION BAY

Area 2 is off the road system in the southern portion of Resurrection Bay from Caines Head out to Aialik Cape (Figure 2). The North Gulf Coast coho salmon fishery starts in this area and most fish are harvested by anglers fishing from boats. There is little or no shore fishery reported here. There were 320 readable coho salmon otoliths collected in 2003 in Area 2, 400 in 2004, and 533 in 2005 (Table 6). In 2004 and 2005, samples were collected across all sampling periods. During 2003, no samples were collected during periods 5 and 6. Technical support was no longer available at the port and rough water and few coho present in the area kept many fishermen closer to Seward. Area 2 is the first area to see substantial coho fishing effort. This fishery starts in late June to early July and tends to taper off in late July. The coho salmon caught in this area feed on abundant food sources found there and then begin to migrate to their spawning areas towards the end of July. Generally, samples are easier to collect from Area 2 in July than in August and September.

During 2003, 2004 and 2005, 23% (SE = 0.027), 19% (SE = 0.020), and 27% (SE = 0.019) of the coho salmon sampled in Area 2 were of hatchery origin. As in Area 1, the proportion of hatchery coho salmon increased as the fishing season progressed. The percentage of hatchery coho salmon sampled during Period 1 was 4% in 2003 and 2% in 2004, but was highest at 21% in 2005. The proportion of hatchery coho salmon collected during August ranged from about 30% to 50% (Table 6). Most coho salmon caught in Area 2 are caught by anglers fishing from either private or charter boats. Private boat anglers account for most of the coho salmon harvested. The proportion of coho salmon otoliths collected from private boat anglers ranged from 53% in 2005 to 72% in 2004 (Table 7). The proportion collected from anglers fishing from charter boats ranged from 28% in 2004 to 47% in 2005. The proportions of coho salmon samples collected from each user group were comparable to the actual harvest of coho salmon in 2003 and 2004 (Table 7). The proportion of samples collected in 2005 was greater than the harvest reported by the SWHS.

Table 8.-Resurrection Bay coho salmon otolith recoveries by sampling period, area, and release site, 2003–2005.

				Hatchery Recoveries								
	Number			Resurrection Bay Releases			PWS Releases			Cook Inlet Releases		Total
2003	of Fish	Unmarked	Marked	ADF&G	CIAA	% of Marked	VFDA	PWSAC	% of Marked	ADF&G	% of Marked	% Hatchery
Area 1												
Jul 5–15	3	2	1	0	0	0%	1	0	100%	0	0%	33%
Jul 16–31	35	26	9	0	0	0%	9	0	100%	0	0%	26%
Aug 1–8	42	21	21	5	3	38%	10	1	52%	2	10%	50%
Aug 9–24 (derby)	96	39	57	24	16	70%	16	1	30%	0	0%	59%
Aug 30–31	90	48	42	26	8	81%	0	8	19%	0	0%	47%
Sep 11–12 (beach)[a]	73	25	48	47	1	100%	0	0	0%	0	0%	66%
Area 1 Total	339	161	178	102	28	73%	36	10	26%	2	1%	53%
Area 2												
Jul 5–15	96	92	4	1	1	50%	0	1	25%	1	25%	4%
Jul 16–31	92	74	18	3	0	17%	14	1	83%	0	0%	20%
Aug 1–8	41	24	17	4	0	24%	10	3	76%	0	0%	41%
Aug 9–24 (derby)	91	56	35	9	0	26%	19	7	74%	0	0%	38%
Area 2 Total	320	246	74	17	1	24%	43	12	74%	1	1%	23%
Area 3												
Jul 5–15	88	81	7	0	0	0%	7	0	100%	0	0%	8%
Jul 16–31	93	75	18	0	0	0%	18	0	100%	0	0%	19%
Aug 1–8	96	66	30	2	0	7%	26	1	90%	1	3%	31%
Aug 9–24 (derby)	95	66	29	2	0	7%	16	11	93%	0	0%	31%
Area 3 Total	372	288	84	4	0	5%	67	12	94%	1	1%	23%
Total	1,031	695	336	123	29	45%	146	34	54%	4	1%	33%

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Table 8.-Page 2 of 3.

2004	Number of Fish	Unmarked	Marked	Hatchery Recoveries: Resurrection Bay Releases ADF&G	CIAA	% of Marked	PWS Releases VFDA	PWSAC	% of Marked	Cook Inlet Releases ADF&G	% of Marked	Total % Hatchery
Area 1												
Jul 1–15	41	40	1	0	0	0%	1	0	100%	0	0%	2%
Jul 16–31	87	78	9	1	2	33%	5	1	67%	0	0%	10%
Aug 1–6	59	46	13	2	7	69%	4	0	31%	0	0%	22%
Aug 7–20 (derby)	96	60	36	18	13	86%	3	2	14%	0	0%	38%
Aug 21–31	61	28	33	17	16	100%	0	0	0%	0	0%	54%
Sep 1–15 (beach)	92	14	78	74	4	100%	0	0	0%	0	0%	85%
Area 1 Total	436	266	170	112	42	91%	13	3	9%	0	0%	39%
Area 2												
Jul 1–15	96	94	2	1	0	50%	0	1	50%	0	0%	2%
Jul 16 –31	96	88	8	4	0	50%	3	1	50%	0	0%	8%
Aug 1–6	87	64	23	4	6	43%	9	4	57%	0	0%	26%
Aug 7–20 (derby)	96	64	32	14	10	75%	7	1	25%	0	0%	33%
Aug 21–31	16	9	7	4	2	86%	0	1	14%	0	0%	44%
Sep 1–15	9	6	3	0	2	67%	0	1	33%	0	0%	33%
Area 2 Total	400	325	75	27	20	63%	19	9	37%	0	0%	19%
Area 3												
Jul 1 –15	91	85	6	0	0	0%	5	1	100%	0	0%	7%
Jul 16–31	92	82	10	2	1	30%	4	3	70%	0	0%	11%
Aug 1–6	96	84	12	6	2	67%	1	3	33%	0	0%	13%
Aug 7–20 (derby)	96	77	19	2	2	21%	8	7	79%	0	0%	20%
Aug 21–31	32	27	5	1	0	20%	1	3	80%	0	0%	16%
Sep 1–15	30	19	11	1	0	9%	0	10	91%	0	0%	37%
Area 3 Total	437	374	63	12	5	27%	19	27	73%	0	0%	14%
Total	1,273	965	308	151	67	71%	51	39	29%	0	0%	24%

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Table 8.-Page 3 of 3.

2005	Number of Fish	Unmarked	Marked	Hatchery Recoveries: Resurrection Bay Releases[b] ADF&G	CIAA	% of Marked	PWS Releases VFDA	PWSAC	% of Marked	Cook Inlet Releases[c] ADF&G	% of Marked	Total % Hatchery
Area 1												
Jul 6–15	8	5	3	0	0	0%	1	2	100%	0	0	38%
Jul 16 –31	32	24	8	0	0	0%	2	6	100%	0	0	25%
Aug 1–12	4	2	2	2	0	100%	0	0	0%	0	0	50%
Aug 13–27 (derby)	89	47	42	20	10	71%	10	2	29%	0	0	47%
Aug 28–Sep 15 (beach)	132	23	109	93	9	94%	2	5	6%	0	0	83%
Area 1 Total	265	101	164	115	19	82%	15	15	18%	0	0	62%
Area 2												
Jul 6–15	196	154	42	4	0	10%	14	23	88%	1	0	21%
Jul 16–31	189	147	42	2	2	10%	18	17	83%	3	0	22%
Aug 1–12	80	57	23	1	0	4%	6	14	87%	1	0	29%
Aug 13–27 (derby)	56	28	28	7	5	43%	7	9	57%	0	0	50%
Aug 28–Sept 15 (beach)	12	4	8	3	1	50%	0	4	50%	0	0	67%
Area 2 Total	533	390	143	17	8	17%	45	67	78%	5	0	27%
Area 3												
Jul 6–15	63	55	8	0	0	0%	2	6	100%	0	0	13%
Jul 16–31	85	71	14	0	0	0%	7	6	93%	1	0	16%
Aug 1–12	102	82	20	3	1	20%	9	7	80%	0	0	20%
Aug 13–27 (derby)	93	62	31	3	5	26%	10	13	74%	0	0	33%
Aug 28–Sep 15 (beach)	42	28	14	0	0	0%	4	10	100%	0	0	33%
Area 3 Total	385	298	87	6	6	14%	32	42	85%	1	0	23%
Total	1,183	789	394	138	33	43%	92	124	55%	6	2%	33%

[a] Does not include 27 unreadable otoliths.

[b] CIAA fed fry (released into Bear Lake) returning in 2005 and VFDA smolt returning in 2005 have the same thermal mark. This only happened in 2005.

[c] CIAA released coho into Homer that had Resurrection Bay Marks in 2004, these fish returned in 2005.

The number of hatchery coho salmon collected was 74 in 2003, 75 in 2004, and 143 in 2005 (Table 8). During 2005, more samples were collected than originally planned. Hatchery-released coho salmon harvested in Area 2 were from Resurrection Bay, Prince William Sound and Cook Inlet release sites. During 2003 and 2005, most of the hatchery recoveries were from Prince William Sound releases, while in 2004, the majority came from Resurrection Bay releases (Table 8). Most of the coho salmon originally released in Resurrection Bay and subsequently harvested in Area 2 were from ADF&G release sites at Seward Lagoon and Lowell Creek, whereas the minority was from CIAA releases at Bear Creek (Table 8). Most of the coho salmon originally released into Resurrection Bay were recovered after August 1.

Coho salmon released from Prince William Sound sites were collected during each sample period in Area 2. A majority of Prince William Sound coho collected in 2003 and 2004 were from VFDA releases, whereas most in 2005 came from PWSAC releases (Table 8). A greater proportion of these fish was also recovered after August 1.

Only 6 coho salmon originally released in Cook Inlet were collected from Area 2: 1 in 2003 and 5 in 2005. Four of these recoveries were collected in July 2005 and one was collected in early August 2005. As in Area 1, significantly fewer marked coho salmon were recovered in Area 2 during July than were recovered after July throughout the entire 3-year study (Cochran-Mantel-Haenszel $\chi^2 = 314.79$, df =1, $P<0.0001$).

AREA 3: NORTH GULF COAST OUTSIDE OF RESURRECTION BAY

Area 3 encompasses all of the North Gulf Coast and Prince William Sound waters outside of Resurrection Bay that anglers returning to the Port of Seward might fish (Figure 2). This is the largest area, but is also farthest from Seward and access is often limited by weather and vessel size. There were 372 readable coho salmon otoliths collected in 2003 in Area 3, 437 in 2004, and 385 in 2005. The Area 3 waters adjacent to Area 2 near Aialik Cape typically have good coho salmon fishing in early July, so sample sizes are generally not difficult to obtain during good weather. A lack of personnel prevented samples from being collected from this area August 25 through September 15, 2003. Rough weather and poor fishing in this area also kept effort to a minimum in this area during August 30–31 and September 11–12 that same year. Samples were collected during all sampling periods in 2004 and 2005.

In 2003 and 2005, 23% (SE = 0.022, SE = 0.021, respectively) of the coho salmon sampled from Area 3 were of hatchery origin (Table 6). In 2004, 14% (SE = 0.017) of the coho salmon sampled were of hatchery origin. Like the other two areas, a greater proportion of hatchery origin coho were collected as the fishing season progressed. The proportion of hatchery coho salmon collected ranged from 7% during Period 1 (July 1-15) in 2004 to a high of 37% collected during the Period 6 (September 1-15) in 2004 (Table 6). Samples collected during July had the lowest proportion of hatchery released coho, and samples collected after July contained the highest proportions of hatchery released coho.

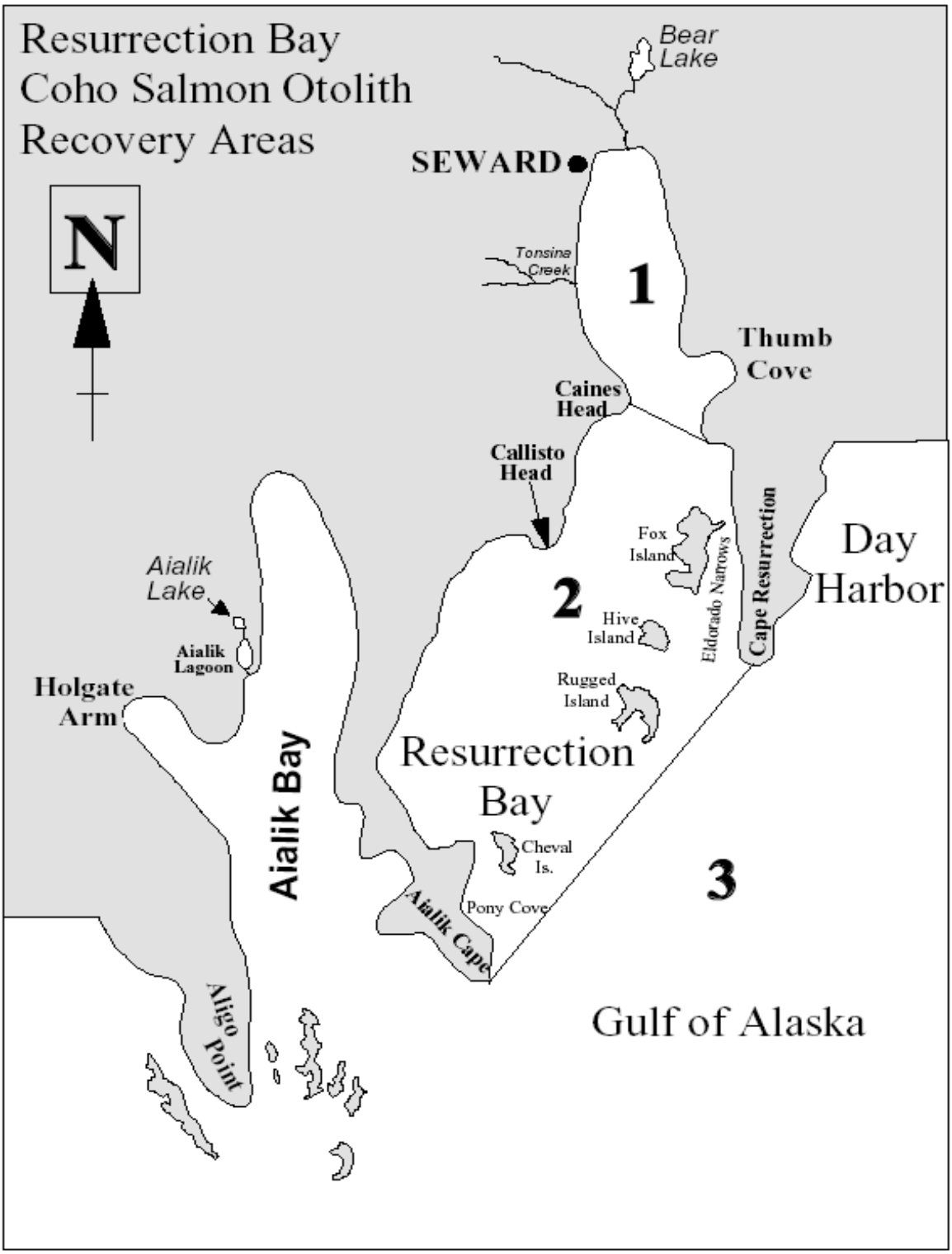

Figure 2.-The Resurrection Bay coho salmon fishery by recovery areas.

Like Area 2, Area 3 has almost no shore fishery, so all samples collected came from boat anglers. Most samples collected each year came from anglers fishing from charter boats (Table 7). The proportion of samples collected from charter boats ranged from 54% in 2003 to 92% in 2005. The proportion of samples collected from anglers fishing from private boats ranged from 46% in 2003 to 7% in 2005. The larger number of samples from charter boats is probably attributed to the location of Area 3. This area is farthest from Seward and is completely exposed to foul weather. Charter boats are generally bigger and faster than privately owned boats allowing them to handle worse weather conditions and move into protected waters more swiftly.

The number of hatchery-released coho salmon recovered in Area 3 was 84 in 2003 and 87 in 2005, whereas only 63 were recovered in 2004 (Table 8). Again, these hatchery-released coho salmon were from release sites in Resurrection Bay, Prince William Sound and Cook Inlet. Most hatchery coho salmon came from VFDA releases in Prince William Sound (Table 8). The number of VFDA coho salmon recovered was 67 in 2003, 19 in 2004, and 32 in 2005, and for PWSAC 12 were recovered in 2003, 27 in 2004, and 42 in 2005. Surprisingly, only 33 coho from Resurrection Bay release sites were recovered over these 3 years. There were 22 coho released by ADF&G at Seward Lagoon and Lowell Creek that were recovered and only 11 CIAA coho that were recaptured. Once again, the proportion of hatchery recoveries generally increased through the season each year.

Only two coho salmon released from Cook Inlet sites were recovered in Area 3. One was sampled during Period 3 (August 1-8) in 2003, and the other during Period 2 (July 16-31) in 2005.

Significantly fewer marked coho salmon were sampled in Area 3 during July than during August and September throughout the entire 3-year study (Cochran-Mantel-Haenszel χ^2 = 314.79, df =1, P<0.0001).

DISCUSSION

The pattern of coho salmon fishing has changed little over the last few years. Coho salmon first show up in late June around Cape Aialik, particularly near Pony Cove, Cheval Island, and Agnes Cove to start the salmon fishing season in the border area between Areas 2 and 3. It is typically easy to obtain coho salmon samples from these two areas during July and early August. In contrast, collecting samples from Area 1, at the head of Resurrection Bay, is usually difficult until August (Table 6).

To achieve the sample size goal of 96 during any given period, samples were collected as evenly as possible throughout the entire period. The main obstacle to collecting samples was rough weather, which often prevented boats from fishing in one area or another. In 2005, another obstacle to collecting samples evenly was the good fishing in Area 2; anglers rarely fished anywhere else. Each angler type was sampled in proportion to their historic catch rates, except in 2005. This design worked well as a guide, but could not always be followed due to the nature of the fishery. For example, during the July 5-15 sampling period, we typically got few samples from Area 1 because coho salmon were rarely found in the head of the bay until later in the season.

Different angler types may also fish more predominately in one area than another. For example, Area 3 is the most exposed to foul weather and is farthest from Seward. Charter

boats are typically bigger and faster than private boats, so make up the majority of vessels fishing in Area 3. Many charter operators travel daily to Montague Island to fish for halibut and other ground fish, but few of them target silver salmon outside the bay. Private boat anglers that do fish Area 3 tend to head east out of Resurrection Bay, fishing at Whidbey and Johnstone bays, and Day Harbor. Conversely, more private boat anglers fish in Area 1, which is closest to Seward. When daily sample goals were not met for an area, samples were made up for as soon as possible from that area. On occasions when a sample guideline could not be met for one user group (e.g., private boat), it was made up for by another group (e.g., charter boat).

One sampling goal was to collect samples by angler type (private boat, charter boat, shore) in the same proportion that these angler-types have harvested coho salmon over the past ten years (1994-2003). However, it was unknown how much each group actually harvested until a year after the sampling event, when the SWHS estimates became available. In 2003 and 2004, the sampled proportions were within a few percentage points of what was actually harvested (Table 7). In 2005, a higher proportion of samples was collected from charter anglers than was reported in the SWHS.

Most of the shore harvest of coho salmon takes place at the beaches adjacent to stocking locations at Lowell Creek and the Seward Lagoon Outflow, both located in Seward. Some shore harvest also takes place at South Beach on Lowell Point and along the road out to this point. Shore anglers also catch some coho off the road on the east side of Resurrection Bay. The steep rocky shoreline found in most of Resurrection Bay and the North Gulf Coast area provides few beaches suitable for fishing from shore or for beaching a boat.

One problem during this study was the use of similar thermal marks on two groups of coho salmon returning in 2005: one marked by CIAA and the other marked by VFDA. The first group was fed fry released by CIAA into Bear Lake in 2003. These fish emigrated out to the ocean in 2004 and returned to the fishery in 2005. The thermal marks were similar to coho salmon released by VFDA at their Solomon Gulch facility in Prince William Sound. This was considered a minor problem, because in the 2 previous years of this study, no coho with the CIAA fed-fry thermal mark were recovered. However, coho salmon with the VFDA mark are some of the most commonly recovered. Another otolith-marking problem occurred when 103,000 coho smolt from a Resurrection Bay stock with a Resurrection Bay thermal mark were released in Lower Cook Inlet at the Homer Spit in 2004. This was also a minor issue because only 10 Cook Inlet marked fish were sampled; 6 in 2005 and 4 in 2003. Although it was a relatively small number of samples, some bias may have been introduced if these fish returned to Resurrection Bay instead of the Cook Inlet where they were imprinted.

In 2003, no samples were collected from Areas 2 and 3 during the last two sampling periods. There was no staff at Seward to collect samples and anglers reported few boats fishing in these areas. Two short sampling events occurred during these last two periods, but no anglers interviewed had fished these two outer areas. This was because there were few coho in these areas and poor weather for fishing. However, there were fish in Area 1, so most boat anglers stayed close to Seward and targeted fish off the beaches. Shore anglers have the most success on the incoming tides that push fish onto the shore within casting distance. The most common method of late season fishing from the shore is snagging.

The overall contribution of thermal marked coho salmon to the Seward salmon fishery ranged from 24% to 33% (Table 6). This is similar to the 34% contribution of hatchery coho reported by McHenry (1986), but lower than the 56% reported by Carlon and Vincent-Lang (1990). Vincent-Lang (1987) estimated that ADF&G stocking programs provided 23% of the coho harvested by the boat fishery operating out of Seward between 1968 and 1987. It is uncertain if these are comparable with the estimates produced during this study because of the changing nature of the fishery. There was much more participation during this study and in recent years than there was during the 1980s. Boats now fish farther from Seward and the charter fleet is much larger. Both of these changes likely increased the number of coho salmon intercepted by anglers fishing out of Seward. The early season fishery at the entrance to Resurrection Bay was nonexistent in the early 1980s and was first explored during the late 1980s. It is also uncertain if earlier studies and this otolith study are comparing coho salmon catches from the same geographic locations. This study found the estimated contribution of hatchery coho salmon harvested within Resurrection Bay (Areas 1 and 2) was 38% (2003 and 2005) and 29% (2004) which falls within the historic range.

The management strategy for coho salmon in North Gulf Coast marine waters focuses on waters inside Resurrection Bay. In these waters, which include both Areas 1 and 2 (Figure 2) the bag and possession limit is 6 coho per day. More than 30% of coho salmon sampled inside Resurrection Bay (Areas 1 and 2) were of hatchery origin. Outside of Resurrection Bay in North Gulf Coast marine waters (Area 3), the bag and possession limit is 3 coho per day. Much fishing effort is also focused during the Seward Silver Salmon Derby. The Derby boundaries also fall entirely within Resurrection Bay (Areas 1 and 2). This Derby has taken place each August since 1956 and attracts anglers from all over Alaska. The late date of the Derby also focuses effort during a time when hatchery coho stocks are most common.

The shore fishery in Area 1 starts in late August and effectively targets the coho returning to nearby release sites. The estimated contribution of hatchery fish in this shore fishery was more than 80% in 2004 and 2005. In 2003, the estimated contribution of marked fish was 66% (Table 6). However, a number of unreadable otoliths (because samples were not cleaned properly or broken) suggest the hatchery contribution was higher. In a 1988 creel survey Carlon and Vincent-Lang (1990) estimated that 81% of the coho salmon harvested off Seward beaches were of hatchery origin.

Coho salmon anglers out of Seward intercept marked fish bound for hatcheries in PWS and Cook Inlet. Coho salmon released from PWS hatcheries, both VFDA and PWSAC, made up about 47% of the marked coho sampled (Table 8). Although marked PWS coho were found in each area, most were sampled from Areas 2 and 3. PWS hatchery coho salmon made up a majority of the marked coho collected, except in 2004 when most were Resurrection Bay released coho salmon. Most marked coho salmon were collected after August 1. The PWS hatchery that contributed the most marked coho to this study was VFDA located in Valdez. Only 1% of the marked coho sampled were released by CIAA into Cook Inlet. Resurrection Bay coho salmon releases made up 52% of the marked coho sampled.

Coho salmon released by ADF&G at the Seward beach sites (Seward Lagoon and Lowell Creek) were recovered at a higher rate than were CIAA coho from Bear Creek. A majority of Resurrection Bay releases was sampled after August 1 in Area 1. The results indicating that ADF&G released coho contributed more to the fishery than CIAA released coho are

consistent to the results found by Carlon and Vincent-Lang (1990) and by Vincent-Lang et al. (1988).

More marked coho were sampled after July, than during July in each area. This may indicate that other coho stocks (stocks not from Resurrection Bay or PWS) are present in July. It could also indicate that the run timing of marked hatchery fish is later than unmarked fish. The origin and status (wild or hatchery) of unmarked coho is not known. These could be wild fish or unmarked hatchery fish.

A coast-wide study (California to Cook Inlet) of the historic recovery of coded wire tagged (CWT) coho salmon (Weitkamp and Neely 2002) showed that hatchery-released coho salmon, from any particular hatchery, can be recovered across a wide range of fisheries. However, there is a far greater chance that a CWT coho would be recovered in waters adjacent to their hatchery of origin. There were 12 distinct geographic recovery patterns discovered, indicating that both hatchery and wild coho salmon stocks may have distinct ocean rearing zones, and may have more genetic diversity than imagined. Wild CWT coho salmon close to these hatcheries had similar recovery patterns suggesting that hatchery coho salmon were a good surrogate for wild fish in determining ocean-rearing ranges. Weitkamp and Neely (2002) included tagged coho salmon as far north as Cook Inlet, but did not study any Kodiak or Afognak coho salmon stocks so Kitoi Bay releases cannot be eliminated as a potential source of coho salmon in Seward Eddy during July.

The Kitoi Bay coho salmon releases contribute a substantial number of adults; typically well over 100,000 (Schwarz et al. 2002) return annually to Afognak area waters. The coho salmon sport fishery near the City of Kodiak has increased since the Kitoi Bay coho salmon releases started, and this increase is assumed to be due to the Kitoi releases (Schwarz et al. 2002). The peak catch appears to be in mid-August, or about 3 to 4 weeks after the peak of the coho fishery at Aialik Cape.

The Alaska Coastal Current is found over the continental self, and travels along the coast of Alaska in a northern direction. This current enables juvenile salmon to move great distances to look for prey while expending little energy (Kondzela and Wilmot 2002). The highest concentration of juvenile coho salmon was found in the Alaska Coastal Current east of PWS. Adult salmon are in the North Gulf of Alaska and presumably travel in the Alaskan Gyre, a counter-clockwise current that dominates the Gulf of Alaska. Both of these currents, the Alaskan Gyre and the Alaskan Coastal Current may have the effect of bringing salmon traveling and feeding in these currents right into the Seward Area.

The North Gulf Coast of Alaska, in and adjacent to Resurrection Bay, is a highly productive area. The Alaska Coastal Current and the Chiswell Ridge, a bathymetric feature that protrudes from Aialik Cape south into the Gulf, is a combination of features that creates a counter-clockwise current called the Seward Eddy (Musgrave et al. 2004). This eddy is rich in nutrients and satellite imagery has shown that it is rich with primary production. This area of localized high primary production appears to attract a diverse community of fish from prey species to predator species. Coho salmon may take advantage of this each spring, starting in June, when primary production has been past its peak for about a month (Musgrave et al. 2004).

The Aialik Peninsula and Chiswell Ridge that juts out into the Gulf of Alaska create the Seward Eddy that is a very important bathymetric feature for coho salmon. This eddy appears

to attract prey species that coho salmon rely upon, and appears to be a major summer feeding area prior to spawning. The small number of marked coho from Cook Inlet sampled indicates that there is some sort of natural boundary, as suggested by Weitkamp and Neely (2002), located between Resurrection Bay and Cook Inlet. Most coho salmon caught in this fishery appear to be stocks east of Cook Inlet to some unknown natural boundary located in the eastern Gulf of Alaska.

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APPENDIX A

Appendix A1.–Sampling schedule for collecting coho salmon otoliths with target sample size guidelines in 2003.

Dates	Private Boat			Charter Boat			Shoreline[a]		
Period 1	Area 1	Area 2	Area 3	Area 1	Area 2	Area 3	Area 1	Area 2	Area 3
Jul-5	7	7	7	4	4	4	all	all	all
Jul-6	7	7	7	4	4	4	all	all	all
Jul-7	7	7	7	4	4	4	all	all	all
Jul-8	7	7	7	4	4	4	all	all	all
Jul-9	7	7	7	4	4	4	all	all	all
Jul-12	7	7	7	4	4	4	all	all	all
Jul-13	7	7	7	3	3	3	all	all	all
Jul-14	7	7	7	3	3	3	all	all	all
Jul-15	7	7	7	3	3	3	all	all	all
Total	63	63	63	33	33	33			
Period 2	Area 1	Area 2	Area 3	Area 1	Area 2	Area 3	Area 1	Area 2	Area 3
Jul-16	6	6	6	3	3	3	all	all	all
Jul-19	6	6	6	3	3	3	all	all	all
Jul-20	6	6	6	3	3	3	all	all	all
Jul-21	6	6	6	3	3	3	all	all	all
Jul-22	6	6	6	3	3	3	all	all	all
Jul-23	6	6	6	3	3	3	all	all	all
Jul-26	6	6	6	3	3	3	all	all	all
Jul-27	6	6	6	3	3	3	all	all	all
Jul-28	5	5	5	3	3	3	all	all	all
Jul-29	5	5	5	3	3	3	all	all	all
Jul-30	5	5	5	3	3	3	all	all	all
Total	63	63	63	33	33	33			
Period 3	Area 1	Area 2	Area 3	Area 1	Area 2	Area 3	Area 1	Area 2	Area 3
Aug-2	12	12	12	8	8	8	all	all	all
Aug-3	12	12	12	7	7	7	all	all	all
Aug-4	12	12	12	7	7	7	all	all	all
Aug-5	12	12	12	7	7	7	all	all	all
Aug-6	12	12	12	7	7	7	all	all	all
Total	60	60	60	36	36	36			
Period 4	Area 1	Area 2	Area 3	Area 1	Area 2	Area 3	Area 1	Area 2	Area 3
Aug-9	5	6	6	2	3	3	2	all	all
Aug-10	5	6	6	2	3	3	2	all	all
Aug-11	5	6	6	2	3	3	2	all	all
Aug-12	5	5	5	2	3	3	2	all	all
Aug-13	5	5	5	2	3	3	2	all	all
Aug-16	5	5	5	2	3	3	2	all	all
Aug-17	5	5	5	2	3	3	1	all	all
Aug-18	5	5	5	2	3	3	1	all	all
Aug-19	5	5	5	2	3	3	1	all	all
Aug-20	4	5	5	1	2	2	1	all	all
Aug-23	4	5	5	1	2	2	1	all	all
Aug-24	4	5	5	1	2	2	1	all	all
Total	57	63	63	21	33	33	18		
Period 5	Area 1	Area 2	Area 3	Area 1	Area 2	Area 3	Area 1	Area 2	Area 3
Aug-25	11	12	12	5	8	8	4	all	all
Aug-26	11	12	12	5	7	7	4	all	all
Aug-27	11	12	12	5	7	7	4	all	all
Aug-30	11	12	12	4	7	7	3	all	all
Aug-31	11	12	12	4	7	7	3	all	all
Total	55	60	60	23	36	36	18		
Period 6	Area 1	Area 2	Area 3	Area 1	Area 2	Area 3	Area 1	Area 2	Area 3
Sep-1	4	6	6	2	3	3	3	all	all
Sep-2	4	6	6	2	3	3	3	all	all
Sep-3	4	6	6	2	3	3	3	all	all
Sep-6	4	6	6	2	3	3	3	all	all
Sep-7	4	6	6	2	3	3	3	all	all
Sep-8	4	6	6	2	3	3	3	all	all
Sep-9	4	6	6	2	3	3	3	all	all
Sep-10	4	6	6	2	3	3	3	all	all
Sep-13	4	6	6	1	3	3	3	all	all
Sep-14	4	6	6	1	3	3	3	all	all
Sep-15	4	6	6	1	3	3	3	all	all
Total	44	66	66	19	33	33	33		

[a] Because there were so few shoreline anglers, samples were collected from "all" anglers encountered unless otherwise specified.